ON THE PROBABILITY OF RAIN [11]

By LOUIS BESSON

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If in a long series of observations we count the number of single rainy days, the number of groups of two consecutive rainy days, of three rainy days, etc., we obtain numbers very different from those which we would be led to expect from computing the probability of rainy days according to the theory of probability.

Herewith are the results of 50 years of observations, 1873–1922, at the municipal observatory of Montsouris, where the record includes 9,580 rainy days in a total of 18,261 days.

TABLE 1.—*The number, S, of groups of k consecutive rainy days*

k	1	2	3	4	5	6	7	8	9	10
S observed	917	614	389	263	181	117	99	63	59	34
S calculated [1]	2,165	1,136	596	313	164	86	45	24	12	7
k	11	12	13	14	15	16	17	18	19	20
S observed	27	19	14	14	6	6	6	1	2	4
S calculated	3	2	0.9	0.5	0.3	0.1	0.07	0.04	0.02	0.01

[1] Let n equal the number of rainy days in a series of N days. If we assume that all the permutations are equally probable, we find the mean number of single rainy days in N days to be $\frac{(N-n)\ (N-n+1)\ n}{N\ (N-1)}$; that of groups of two rainy days to be $\frac{(N-n)\ (N-n+1)\ n\ (n-1)}{N\ (N-1)\ (N-2)}$, and so on. These formulae were given by Grossmann (Achiv der Deutsche Seewarte, 23, Jahrg., 1900, p. 34).

In addition there were observed 3 groups of 21 days, 2 groups of 25, 2 of 27, 1 of 29, and 1 of 31.

The short series of rainy days are clearly much less numerous than they ought to be; and on the other hand there are long series which seem, *a priori*, to be impossible.

The cause of this disagreement is evidently as follows: The probability of a rainy day is not independent of past conditions. One is not justified in considering that the probability is constant and equal to the quotient of the number of rainy days divided by the total number of days of observation (0.525 at Montsouris).

From the results of observations set forth in Table 1, we may derive [12] the actual probability of rain if we know that it has rained the day before, rained during the two preceding days, during the three preceding days, etc.

TABLE 2.—*Probability of rain, p_k, when the number, k, of rainy days is known*

k	1	2	3	4	5	6	7	8	9	10
p_k	0.704	0.714	0.727	0.737	0.744	0.751	0.749	0.756	0.754	0.769
k	11	12	13	14	15	16	17	18	19	20
p_k	0.772	0.78	0.78	0.78	0.81	0.80	0.81	0.82	0.80	0.78
k	21	22	23	24	25	26	27	28	29	30
p_k	0.81	0.84	0.8	0.8	0.7	0.7	0.6	0.7	0.5	0.5

Thus the probability of rain, which is 0.525 if we ignore what has taken place the day before, rises abruptly to 0.704 if we know that it has rained. The probability continues to rise, but more and more slowly, as the number of successive rainy days also rises, reaching 0.8 after 15 days of rain. Since the later values are less exact because of the small number of long rainy periods, we can not be sure that the probability of rain begins at length to decrease, as the above figure would seem to indicate.

Similar computation has been made for each of the 12 months separately with a view to discovering if the influence of the past weather on future weather varies in the course of the year. It appears that we have a satisfactory measure of that influence in the following ratio:

$$R=\frac{p_1-p}{1-p_1},$$

p being the general probability of a rainy day and p_1 the probability of a rainy day after it has rained the day before. The ratio R varies from 0 to 1. Whatever p may be, R is 0 if there is no influence from rain the day before and is equal to 1 if such rain assures another rain. This ratio may be called the *coefficient of persistence*.

TABLE 3.—*Monthly and annual values of the coefficient of persistence R.*

	J	F	M	A	M	J	J	A	S	O	N	D	Year
p	0.582	0.558	0.551	0.530	0.499	0.476	0.470	0.456	0.452	0.529	0.574	0.618	0.525
p_1	0.708	0.760	0.713	0.693	0.742	0.650	0.679	0.641	0.649	0.688	0.762	0.767	0.704
R	0.30	0.46	0.36	0.35	0.49	0.33	0.39	0.34	0.36	0.34	0.44	0.39	0.38

Almost all the values found for the different months are very close to the annual mean, and the deviations appear to be purely fortuitous.

On the other hand, if we divide in half the series of 50 years and compute the coefficient R for each of the 25-year periods, we obtain 0.40 and 0.35, values only slightly different from one another, notwithstanding the fact that these two periods showed very dissimilar rainfall regimes.

As a first approximation, then, we may regard a coefficient of persistence of 0.38 as a constant for the climate of Paris.

[11] Comptes Rendus, 178, no. 21, May 19, 1924, pp. 1743–1745.

[12] It is clear that if we designate as S_k the number of groups of K consecutive rainy days, and by p_k the probability of rain after k days of rain, n being always the total number of rainy days, we have:

$$p_1=\frac{S_2+2S_3+3S_4+\cdots}{n},\quad p_2=\frac{S_3+2S_4+3S_5+\cdots}{S_2+2S_3+3S_4+},\ \text{etc.}$$

SUMMARY OF CORRELATIONS BETWEEN HAWAIIAN RAINFALL AND SOLAR PHENOMENA

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Rainfall correlated with—	Correlation coefficient r	Probable error e	r/e	Remarks
Sunspot numbers:				
Yearly	−0.012	±0.164	0.1	Probably none.
Monthly	+0.159	±0.043	3.7	Doubtful.
Changes in spot numbers:				
Yearly, synchronous	+0.070	±0.163	0.4	Probably none.
Six months before	−0.056	±0.164	0.3	Do.
Six months after	+0.459	±0.130	3.5	Probable.
Monthly average function	+0.092	±0.044	2.1	Possibly small.
Radiation intensity:				
Yearly	−0.200	±0.153	1.3	Doubtful.
Monthly average function	+0.077	±0.0313	2.5	Probable (small).
Changes in radiation intens'ty:				
Yearly, synchronous	+0.245	±0.152	1.6	Possible.
Six months before	+0.165	±0.158	1.0	Doubtful.
Six months after	+0.249	±0.152	1.6	Possible.
Average function monthly	+0.176	±0.031	5.7	Probable.

NOTE.—The above correlation coefficients were furnished by Mr. Cox in connection with some related work; they are published for the benefit of those interested in correlation between solar and terrestrial data.—EDITOR.